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Abstract

The data acquisition system being built for PBFA II incorporates several new advanced technology features. The system will have 80 new waveform recorders with a 1.35 GHz sampling rate, 250 MHz bandwidth and 10,000 sample record length. A fast analog multiplexer will be used to enable recording multiple signals on each recorder. The accelerator performance monitor system will use time interval digitizers with a time window of ± 8 msec. This long window and the pretrigger feature will provide data for a thorough analysis of accelerator prefires. The calibration system will automatically route precision dc levels, sine waves and fast-rise pulses to the waveform recorders. The waveform recording system is being characterized using special multi-channel, high-level simultaneous pulse generators. The system computer has a 32-bit CPU, 350 Mbytes of disc storage and a virtual memory operating system. All software is being written in Fortran 77.

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Introduction

Sandia National Laboratories has been using automated on-line computer controlled data acquisition systems (DAS) on its large pulse power accelerators since 1976.^{1,2} These systems typically consist of high-speed waveform recorders, single-parameter digitizers, automated calibration, signal switching, and attenuation subsystem all controlled by a minicomputer. All the software has been written in-house in Fortran. The data acquisition system being built for PBFA II incorporates several new advanced technology features. Fig. 1 shows a block diagram of the various components in the DAS.

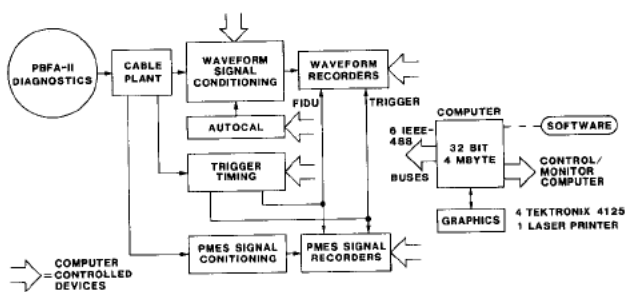


Figure 1. Block diagram of the various components of the PBFA II data acquisition system.

Waveform Recording

The most significant improvement is in the area of waveform recorders. In the past we have used only Tektronix R7912 and 7912AD Transient Digitizers because they were the only devices on the market with adequate bandwidth and sampling rate. The main disadvantages of the 7912's are high cost and short record length. The PBFA II DAS has 22 7912AD's with 220 MHz 7A16P vertical amplifiers.

We have also ordered 80 model 6880 waveform recorders from LeCroy Research Systems. The 6880 recorder has a fixed sample rate of .742 ns, an analog bandwidth of 250 MHz, and a record length of 10,000 samples. The sensitivity is fixed at 500 mv full scale with an offset variable over a range of $\pm 1/2$ full scale. In addition the 6880 has two input signal ports which may be added. The two ports have an interchannel reverse isolation of 30 dB. We will use the second port for adding a fiducial timing pulse onto each waveform.

The 6880 is a triple-wide CAMAC module. Up to six 6880's can be mounted in a CAMAC crate. The 6880's can be controlled by a standard CAMAC crate controller. However it is more desirable to use the LeCroy model 6010 Magic CAMAC controller. The main advantages of the 6010 over a normal CAMAC crate controller are that it has built-in calibration and data correction software for the 6880. And the 6010 provides for local control of the 6880. The 6010 may be interfaced to host computers via either RS-232-C or IEEE-488 General Purpose Instrumentation Bus (GPB) links. We have chosen to use the GPB link on PBFA II. The GPB provides much faster data transfer and reduces the number of controller interfaces in the computer. The 6010 programming language conforms to IEEE Guideline 728-1982 "Recommended Practice for Code and Format Convention" for GPB systems. All control messages are in a high level readable ASCII format, as opposed to binary. Large data blocks are transferred in blocked binary format. The 6010 supports a high level language specifically for controlling the 6880's. The controller also supports a second control language for controlling other types of CAMAC devices. We are using the CAMAC language to control 48 bit digital output modules which drive the relays in the programmable attenuators associated with the 6880's.

The first 6880's are expected to be delivered in the summer of 1985. We have received a 6010 controller and a 6880 simulator and are using these to develop the system software. Fig. 2 shows an example of a signal recorded with a prototype version of the 6880. This signal is a digitized 44 MHz sine wave. The 6880 accuracy in this case is 5.0 effective bits. The prototype unit achieves 5.0 effective bits up to 170 MHz. The accuracy performance will be improved to at least 6.5 effective bits at 50 MHz. These performance accuracies are better than the 7912AD and are adequate for our needs.

The 7.4 μ sec record length of the 6880 is several times longer than nearly all pulse power and experiment signals. Thus we would like to record more than one signal on each recorder. Voltage and current signals tend to be nonzero for a long time after the initial period of interest. This means that they cannot simply be added at the recorder input. Thus a fast wideband multiplexing switch is required to selectively route different signals to the digitizer. Phillips Scientific makes a model 744 Linear Fan-in/Fan-out NIM module which can be configured as a multiplexer. We have ordered enough of these modules plus gate pulse generators to switch and record up to four signals on each 6880. Switching speed will be less than 2 ns. Analog bandwidth will be dc to 250 MHz. The multiplexer will handle signal amplitudes up to ± 2.5 v with nonlinearity distortion less than .5%. We plan to use the sequential firing characteristics of the accelerator to avoid placing delay lines in most signals. Delay lines will probably be required for recording multiple experiment signals. The fast multiplexer system should be ready to support accelerator characterization testing in the first half of 1986.

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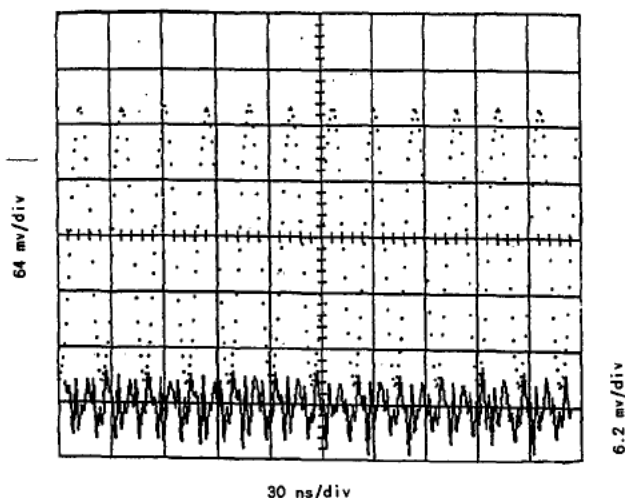


Figure 2. Top: 44 MHz sine wave digitized on a LeCroy 6880 recorder. Bottom: residuals between least squares fit and digitized data.

Performance Monitoring and Evaluation System (PMES)

The PBFA II DAS was originally designed to have about 300 channels of single-parameter recorders to monitor the accelerator pulse power performance. This system, called PMES, measures the fire-time of all critical pulsed power components using time interval digitizers. PMES measures signal amplitudes using peak detector and gated time integral digitizers. However the ability to record multiple signals on the 6880 waveform recorders may eliminate many of the single-parameter recorders until other diagnostic needs arise later in the PBFA II program.

We will continue to monitor accelerator and DAS timing using time interval recorders. The most significant improvement is the use of LeCroy 4208 time interval

digitizers in place of the LeCroy 2228 units.³ The main advantage of the 4208 is the ± 8 msec time window vs. the 500 ns time window on the 2228. We have wired all signals subject to prefire into a single PMES trigger source. Thus when a prefire occurs, there is a very high probability of capturing all of the timing information with the pretrigger and long time window of the 4208's. The timing data in turn tells the operators which component caused the system to prefire. This information is valuable in troubleshooting the accelerator because the maintenance crew knows where to look for the problem.

Cabling

The PBFA II cabling system from the RF shielded room to the diagnostic monitors in the accelerator is very similar to that used on PBFA I [2]. The first part of each cable run consists of RG-331 1/2" semirigid foamflex cable running in RF shielded wireways from the DAS room to 24 feedthru ports in and around the machine. The facility has 760 cables 155' long. All cables have been cut to the same length to within $\pm .3$ ns. The second part of the run consists of RG-214 cable run in flexible solid convolute RF shield tubing from the feedthru ports to each individual monitor or vacuum feedthru. The final part of the cable system for experimental diagnostics inside the vacuum chamber will be provided by the experimenters.

The major improvement in cabling is the method for routing signal cables inside the RF shielded room. This system is described in another paper in these proceedings [3].

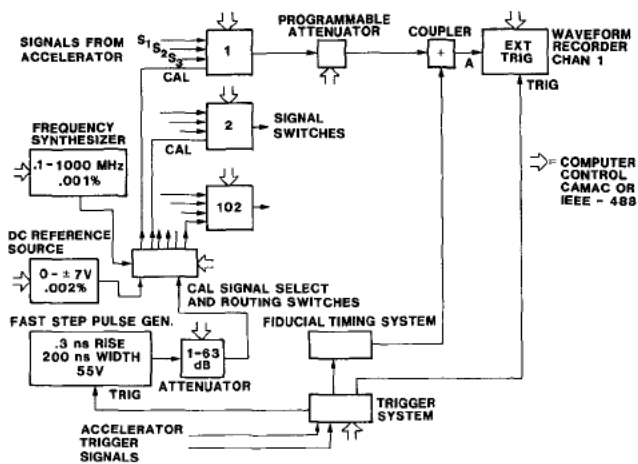


Figure 3. Automatic calibration system hardware configuration.

Calibration

Previous DAS facilities have used Tektronix model 1340 Data Coupler automatic calibration and signal switching

systems.⁴ There have been no major problems with these, but they are now obsolete. For PBFA II we have assembled the automatic calibration and signal switching system using discrete pieces of equipment for maximum flexibility. A block diagram of this subsystem is shown in Fig. 3. The major new capability is the addition of the pulse calibration generator and the method of switching the calibration signal sources to the waveform recorders. On the PBFA I facility the cal source signals were "daisy-chained" to the calibration input of each signal switch using "straight-tees". This signal distribution method was acceptable for dc and steady state periodic signals. However it does not work for pulsed signals because of the 25 ohm impedance mismatches at each tee. In the new system the first switch selects the calibration source which is then routed to a single recorder channel in the next three switch stages. This eliminates the impedance mismatches.

We are currently only using the pulse calibration source to automatically test and verify the high frequency response of the waveform recorders. The amplitude calibration factors used in correcting the data from the digitizers are generated using the dc reference source. We plan to send the pulse calibration generator and its programmable attenuator to the National Bureau of Standards for calibration. We will then use the pulse calibration waveform for generating amplitude correction factors.

The PBFA II DAS is also being characterized as a system. We are using two special multi-channel, high-level, simultaneous pulse generators built in-house to measure the system amplitude accuracy, timing simultaneity, and risetime. The parameters of these pulsers are summarized in Table 1. We have independently calibrated the amplitude of each output pulse. The pulser is placed at the end of a number of actual signal cables and the pulses are recorded using all the normal DAS hardware and software. The results are then compared to the pulser specifications. The recording system uses the programmable attenuators and software cable compensation.

Using this method we have achieved inter- and intra-shot timing simultaneity of $\pm .4$ ns at 10 ns/div. recording speed. The system risetime was measured to be 2.2 ns. This risetime is consistent with a 1.7 ns pulse being recorded thru a 220 MHz amplifier. The average error in measuring the pulse amplitudes was 2.6% with a peak error of 5%. The major cause of the error is a systematic overshoot with a settling time of 1 μ sec in the 7912AD's. This phenomenon is shown in Fig. 4. The pulse is from a Tektronix PG506. The specified flatness is .5% after 10

Table 1. Characteristics of multi-channel system characterization pulsers.

Parameter	Fast Pulser	Slow Pulser
Number of channels	20	60
Pulse amplitude	151 v	100 v
Pulse shape	Rectangular	Rectangular
Pulse risetime	1.7 ns	9 ns
Pulse width	35 ns	62 ns

ns. We manually corrected the data on the characterization shots for the overshoot and achieved an average error of .7% and a peak error of 2.5%. The remaining errors are due to the ripple in the characterization pulse and the resolution of measuring the amplitude. This systematic overshoot indicates a need to compute deflection factors using a pulse calibration for very accurate recording of pulses less than 1 μ sec. However a pulse calibration will give erroneous data for longer pulses.

Computer System and Software

Previous data acquisition systems have used 16 bit minicomputers with limited program memory address space. For the PBFA II DAS we have purchased a Data General MV-8000 II computer system. This computer has a 32-bit CPU, 4 Mbytes of memory, 350 Mbytes of disc storage and a virtual memory operating system. The virtual memory feature makes software development much easier than on machines with limited address space. The main reason is that large programs do not have to be manually divided into overlaid segments. This system was selected via a competitive procurement. The Data General computer is about three times faster than 16-bit minicomputers in performing floating point computations. However the computer seems no faster than the smaller machines in acquiring and storing data. We plan to investigate this slow response and hopefully modify the DAS software or the operating system configuration to speed up data collection.

We have experienced maintenance problems with the MV-8000 II computer. There have been four instances where the computer was down for more than two days. The computer response time to software development and data reduction users is unacceptably slow while the data acquisition program is running. For these reasons we have purchased a second computer system. The second system will be used for software development and data reduction and will act as a backup for the data acquisition computer in case of hardware failure.

The recorded data will be displayed on high resolution Tektronix 4125 raster graphic terminals. These terminals have color capability and multiple graphic planes. We have not yet developed software to take advantage of these features. The major problem we have found with these terminals is the lack of an optimum alphanumeric mode character size. We would like to display and screen edit lines of text with about 120 characters, but the terminal only has character sizes for 80 and 160 characters per line. The 160 character per line size is too small to be read comfortably. The system also has a laser printer for making high quality graphics hard copies.

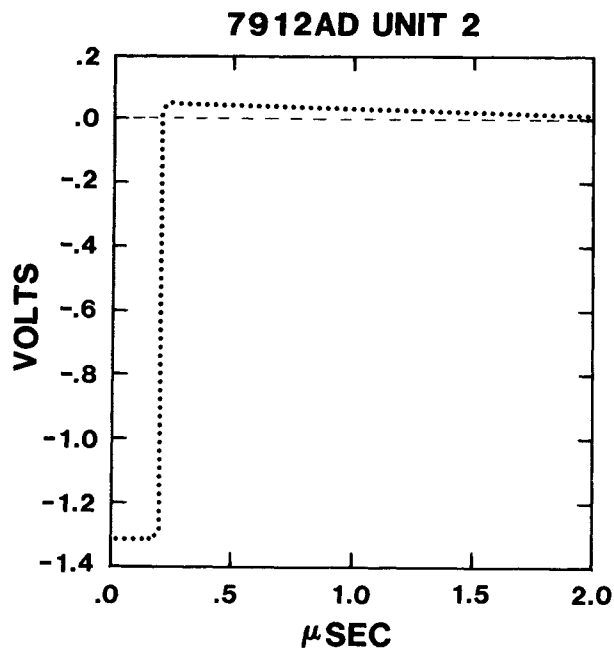


Figure 4. Pulse from a Tektronix PG506 pulse generator recorded on a 7912AD Transient Digitizer indicating 5% overshoot with a settling time of 1 μ sec.

The software system contains the following major programs:

- AQD - waveform and single parameter data acquisition program,⁵
- IDR - interactive/command file data reduction and hardware control program,
- ACL - automatic waveform recorder calibration program,
- PMCAL - PMES system semiautomatic calibration program,
- PUDB/PMO - PMES data base data transfer and interactive/command file data reduction programs.

These programs are functionally similar to the ones developed for the PBFA I DAS [2]. They have been converted to Fortran 77 and reorganized to eliminate the overlaying. Detailed "help" messages are being incorporated into all programs.

We have designed a very versatile disc file data structure for storing all types of data files. The data structure supports directoried access for random length data records. The logical data records are stored in fixed size physical records. The directory is maintained in a separate file from the data. This data structure provides fast access, efficient use of disc space and file expandability limited only by disc space available.

We are using a graphics package called Weasel which was written internally at Sandia by the central computer organization. Weasel contains a very useful subset of the plotting capabilities provided in the commercial package DISSPLA sold by ISSCO. Weasel uses a virtual device interface software package also developed by the Sandia central computer group to communicate with a large variety of terminal types and graphic printers. The major problem with this package is that it will only support one device at a time within a program. We will have to overcome this problem to produce graphs on both the terminal and the laser printer from the same program.

The use of Fortran 77 Character variables and file access statements will make the software transportable among different makes of computers. We have a version of the interactive data reduction program, IDR, running on a Digital Equipment Corp. VAX computer. There are some

minor differences in the Fortran OPEN statement between the DEC and Data General computers. The most serious obstacle to transportability is the IEEE-488 support package. We are using software which is unique to Data General.

The PMES data are maintained using a commercial data base software package called RIM. This software is sold by RIM Technology Inc. It is also available for VAX computers. We will be linking the DAS computer to a central unclassified VAX 730 in the pulse power research area. Data files will be transferred off-line from the 730 to classified VAX 780 and 782 computers. Users will then be able to access the PBFA II data from their offices. We will eventually also maintain the PMES data base on one of the VAX's using RIM.

Conclusion

Many significant improvements have been made in the PBFA II data acquisition system over previous systems. These improvements will provide many more waveform channels with more accurate data than have been available previously. The enhanced pretrigger capability of the PMES system will make machine maintenance easier. The increased computing power available to users will greatly enhance post-shot data analysis. Finally the use of Fortran 77 and the virtual memory operating system will make software maintenance easier.

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We would like to thank Wes Helgeson of the Pulsed Power Research Division at Sandia for designing and providing the multi-channel system characterization pulse generators. Both of these units have proved extremely valuable in calibrating the system.

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